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Analytical solution for tension-saturated and unsaturated flow from wicking porous pipes in subsurface irrigation: The Kornev-Philip legacies revisited

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Abstract

© 2017. American Geophysical Union. All Rights Reserved. The Russian engineer Kornev in his 1935 book raised perspectives of subsurface “negative pressure” irrigation, which have been overlooked in modern soil science. Kornev's autoirrigation utilizes wicking of a vacuumed water from a porous pipe into a dry adjacent soil. We link Kornev's technology with a slightly modified Philip (1984)'s analytical solutions for unsaturated flow from a 2-D cylindrical pipe in an infinite domain. Two Darcian flows are considered and connected through continuity of pressure along the pipe-soil contact. The first fragment is a thin porous pipe wall in which water seeps at tension saturation; the hydraulic head is a harmonic function varying purely radially across the wall. The Thiem solution in this fragment gives the boundary condition for azimuthally varying suction pressure in the second fragment, ambient soil, making the exterior of the pipe. The constant head, rather than Philip's isobaricity boundary condition, along the external wall slightly modifies Philip's formulae for the Kirchhoff potential and pressure head in the soil fragment. Flow characteristics (magnitudes of the Darcian velocity, total flow rate, and flow net) are explicitly expressed through series of Macdonald's functions. For a given pipe's external diameter, wall thickness, position of the pipe above a free water datum in the supply tank, saturated conductivities of the wall and soil, and soil's sorptive number, a nonlinear equation with respect to the total discharge from the pipe is obtained and solved by a computer algebra routine. Efficiency of irrigation is evaluated by computation of the moisture content within selected zones surrounding the porous pipe.

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Keywords

hydraulic-pressure heads, irrigation by siphoning-wicking, Kirchhoff potential, Laplace/steady-state quasi-linear form of Richards' equation, method of fragments with continuity of pressure

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